GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 1/28/80

Project Title: Dual ~~Seiren~~ Modulator

Project No: A-2543

Project Director: Mr. J. Clark Butterworth

Sponsor: Brunswick Corporation

Agreement Period: From 1/2/80 Until 4/1/80

Type Agreement: Verbal Authorization per GRH/GTRI ltr dtd 12/20/79

Amount: $10,666 (Phase I)

Reports Required: Monthly Progress Reports; Final Report

Sponsor Contact Person (s):

Technical Matters	Contractual Matters (thru OCA)
Mr. Sam Wozniak, Technical Director Brunswick Corp. Corporate Officers Defense Division Building G1 Brunswick Plaza Skokie, Illinois 60077	

Defense Priority Rating: N/A

Assigned to: RAIL/RED (School/Laboratory)

COPIES TO:

- Project Director
- Division Chief (EES)
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- Project File (OCA)
- Project Code (GTRI)
- Other

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: September 27, 1980

Project Title: Dual Modulator

Project No: A-2543

Project Director: Mr. J. Clark Butterworth

Sponsor: Brunswick Corporation; Skokie, Illinois 60077

Effective Termination Date: 4/1/80

Clearance of Accounting Charges: ---

Grant/Contract Closeout Actions Remaining:

- X Final Invoice ~~and Closing Documents~~
- _ Final Fiscal Report
- _ Final Report of Inventions
- _ Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other _____

Assigned to: RAIL/RED (~~School~~/Laboratory)

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Project File (OCA)
Project Code (GTRI)
Other _____

CA—4 (1/79)

A-2543

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

6 February 1980

Brunswick Corporation
Corporate Officer
Defense Division
Building G1
Brunswick Plaza
Skokie, Illinois 60077

Attention: Mr. Sam Wozniak

Gentlemen:

This monthly progress letter summarizes activities on the above referenced project during the month of January 1980. During this month, activities centered about definition and investigation of possible modulator configurations; with emphasis on determining the feasibility of these dual modulator techniques for Brunswick's specific application. Also during this month, a meeting was held between Mr. Sam Wozniak of Brunswick Corporation and the Georgia Tech project staff for additional clarification and definition of program objectives and constraints.

As a result of the investigations carried out during January, it has been decided to concentrate on three basic modulator approaches and to investigate these in additional detail. The specific approaches being considered are the use of separate modulators, combined in a common pulse transformer in order to generate the required pulses; the use of a single pulse forming network and switch with a suitably tapped delay line in order to generate the appropriate pulses; and alternate charge and discharge of a single pulse forming network through two pulse transformer primaries in order to generate the appropriate pulse bursts. Several key factors have been identified which impact the applicability of these techniques for Brunswick's specific application, and these will be pursued in additional detail during the coming months.

In addition to the above technical efforts, some unofficial estimates of the cost impact on the program of several levels of

changes in schedule and testing and parts qualification requirements were prepared. These have been submitted to Brunswick in a separate letter, and we would be glad to submit a formal proposal reflecting any such changes, should it become necessary.

Financial Status

Financial charge sheets are not yet available for January 1980, but is is estimated that approximately $2,000 were spent on the contract as of 1 February, 1980.

Submitted by

[redacted]

J. Clark Butterworth
Project Director

JCB:jct

Approved by

[redacted]

Nicholas C. Currie
Chief, Radar Experimental Division

A-2543

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

5 March 1980

Brunswick Corporation
Corporate Officer
Defense Division
Building G1 Brunswick Plaza
Skokie, Illinois 60077

Attention : Mr. Sam Wozniak

Gentlemen:

This monthly progress letter summarizes activities on the "Dual Modulator" project during the month of February 1980. A meeting was held at Georgia Tech EES on 13 February with Sam Wozniak, Geoffrey Thornber, and project personnel. Further discussions of the modulator and magnetrons characteristics were explored. Better definitions and understanding at output signals from transmitter are now available to aid in the decision for the best suited approach.

As a result of the February meeting and further explorations the most feasible approach seems to be multiple modulators combined in a common output pulse transformer. This method gives greater flexability in amplitude, timing and pulsewidth and should yield a higher fidelity output signal. However, the package size and weight of this configuration is probably the greatest, therefore, the other methods will not be dismissed.

The preliminary design of a Charging Reactor, a Bias Reactor, and a Pulse Transformer has been completed. The above items have been fabricated and baked and are now ready for test in a breadboard modulator using a 7208B Magnetron. This test setup will be for the maximum length of all pulses in one modulator.

The effort for next month will be to continue the development of the multiple modulator concept and to test the components assembled in the breadboard modulator. Another meeting is scheduled for 19 March 1980.

Financial Status

Financial charges to the contract in January 1980 were $1526 while estimated charges for February 1980 are $2120. Total estimated charges to date are $3646.

Submitted by,

[redacted]

J. Clark Butterworth
Project Director

JCB:jct

Approved:

[redacted]

Nicholas C. Currie
Chief, Radar Experimental
Division

H-2572

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

7 April 1980

Brunswick Corporation
Corporate Officer
Defense Division
Building G1 Brunswick Plaza
Skokie, Illinois 60077

Attention : Mr. Sam Wozniak

Gentlemen:

This progress letter summarizes activities on the "Dual Modulator" project during the month of March 1980. Laboratory experiments were conducted to evaluate some of the major components involved in the modulator. Two areas were identified as possible problems: 1) The SCR switch exhibited excessively high initial voltage drop from anode to cathode under conditions within their given specification. 2) The capacitors used in the test PFN (Cornell-Publisher WMF Series) introduced an excessive amount of self-inductance which may limit the number of sections in the PFN and effect the pulse shape.

A meeting was held on March 19, 1980 attended by Sam Wozniak, Geoffery Thornber, George Ewell, David Ladd and Clark Butterworth. The problem with the SCR and the capacitor was discussed along with other concerns. Battery operation of the Dual Modulator was considered and an efficiency of at least 70% was felt to be a design goal. The pulse shape was discussed with emphasis placed on the extreme squareness ratio 10/20:1 and the ripple goal of 1 dB. Both specification for squareness and ripple seem difficult but we feel they are achievable.

At the March meeting additional time and funding was discussed and a request for extension was submitted to Brunswick Corporation. After considering this request Mr. Wozniak has asked that we not pursue the extension in light of the fact that the DOD contract should be eminent. Mr. Wozniak requested all effort except for technican work on capacitors be stopped as of this time in order to extend the original funding as much as possible.

The effort for next month will be to continue work on the low self-inductance capacitors for use in the Pulse Forming Network.

Financial charges to the contract through March 1980 are estimated at $7900.

Submitted by,

[redacted]

J. Clark Butterworth
Project Director

JCB:JCT

Approved:

[redacted]

N. C. Currie
Chief, Radar Experimental Division

A-2543

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

9 June 1980

Brunswick Corporation
Corporate Officer
Defense Division
Building G1 Brunwick Plaza
Skokie, Illinois 60077

Attention: Mr. Sam Wozniak

Gentlemen:

This final letter report summarizes investigations carried out for Brunswick Corporation under an industrial agreement designated as Georgia Tech Project A-2543. The effective date of the program was 2 January 1980, and the original duration of Task 1 was to be three months; however, by mutual agreement this time period was extended until the decision by Brunswick Corporation on 15 May 1980 to terminate all activities under the program.

The purpose of the investigations carried out under A-2543 was to develop a dual modulator for a specific application. This modulator would be used to pulse a microwave magnetron in a 3 μs on, 3 μs off sequence length of 4 or 5 pulses. In practice, two of these modulators would be used and the resulting RF pulses interleaved. The duty cycle of the magnetron would be less than 0.015, the magnetron would operate at 17 to 19 kV and 13 amps peak current, and would have a complex PRI sequence with a minimum 735 μs interpulse period. A simultaneous multipactor trigger of several hundred volts amplitude would be required.

Packaging of the system would be in a twelve inch diameter cylinder with a two inch diameter hole through the middle with length as required. Power would be from a 28 volt battery source, and relatively stringent shock and vibration requirements were applicable. The outside of the cylinder would be in contact with the cold surface during operation, and the system would be required to withstand a -55°C cold soak period.

The entire program was divided into several tasks, only the first of which was funded and pursued. This task was devoted to the identification of possible approaches and detailed investigation of key technical problem areas.

I. Concept Identification

A number of possible approaches have been identified which held some promise for this application. These include the use of multiple separate modulators with the outputs combined to generate the desired waveform, charging and discharging of a single PFN

through different pulse transformer windings, the use of PFN reflections and delays to generate the required output pulse sequence, the use of a single switch and multiple saturable reactor delays for timing, and the use of several Darlington modulator configurations, and finally the utilization of a compact hard tube modulator.

II. Selected Approaches

After careful consideration of the requirements, and conferences with Brunswick Corporation personnel, the use of the multiple modulator approach appears to be the most reasonable and attractive option which employs low voltage solid state switching. In the event that higher pulse rectangularity is desired, it is suggested that the use of a hard tube modulator utilizing special high perveance vacuum tubes be considered for this application.

In considering the multiple modulator approach, several key technical problem areas were identified, primarily the control of heating in the SCR switches, the design of the pulse transformer, and the ability to achieve the desired squareness ratio of the output pulse.

A preliminary design of the pulse transformer was carried out. Indications are that when DC bias is used that a reasonable size pulse transformer would be capable of sustaining the entire 15 μs pulse combination. In this type transformer the heat could be satisfactorily removed. Unfortunately, conventional designs evidence relatively high leakage inductance associated with the high step-up turns ratio required. This in turn results in an impedance of the transformer somewhat higher than the magnetron impedance. The high leakage inductance and thus, impedance mismatch results in relatively long rise time which limits the ratio of rise to pulse duration to be on the order of 10 or 20:1.

Another problem which was investigated was heating of the SCR switch a saturable reactors once would be used to minimize this heating. Unfortunately, this approach places a limit on the number of PFN sections. Design limits the saturated inductance of the saturable reactor to less than the end PFN section inductance. Again, practical limits appear to constrain the ratio of rise time to pulse width to the order of 10 or 20:1.

In an attempt to circumvent both the SCR switching problems and the rise time limitations associated with the high pulse transformer set-up ratio, the use of RBDT's as switch elements was investigated. Such devices have the advantage of higher operating voltages reducing pulse transformer turns ratio requirements. RBDT's also have increased di/dt ratings eliminating the necessity for saturable reactors and the SCR switch.

III. Laboratory Evaluation

As part of the Task 1 activities, laboratory evaluations of pulse transformer response, RBDT switching characteristics, and the behavior of saturable reactors when used to control current rise in SCR switches were all initiated. The pulse transformer investigation indicated good agreement with design values, but operation at full pulse width and operating voltage was not achieved before early termination of the program. The RBDT investigation were limited to an initial design of a single modulator section

using T-40 RBDT's, and partial fabrication of capacitors for the pulse forming network for a breadboard evaluation of this design.

Use of saturable reactors in connection with SCR's to control the di/dt limitation produced results at considerable variance with those expected. In order to probe this further, test set-ups to determine saturated inductance and voltage hold-off time of the saturable reactors were implemented in the laboratory and a detailed investigation of the reasons for variance between predicted and achieved performance was underway.

On 15 May 1980, Mr. Sam Wozniak communicated Brunswick's desire to terminate activities on the dual modulator program. As a result, activities have been suspended, and this Final Technical Report prepared. With the submission of this report, all activities currently planned to be carried out under A-2543 have been completed. However, if additional information is desired, or clarification of any points would be useful, please do not hesitate to make your requirements known.

Submitted by,

J. Clark Butterworth
Project Director

JCB:jct